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# Applying Independent Verification and Validation to Automatic Test Equipment

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# Applying Independent Verification & Validation to ATE

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**Abstract** - This paper describes a general overview of applying Independent Verification and Validation (IV&V) to Automatic Test Equipment (ATE). The overview is not inclusive of all IV&V activities that can occur or of all development and maintenance items that can be validated and verified, during the IV&V process. A sampling of possible IV&V activities that can occur within each phase of the ATE life cycle are described.

## I. INTRODUCTION

Automatic Test Equipment (ATE) is becoming increasingly more sophisticated and complex, with an even greater dependency on software. With the onset of Versa Modular Eurocard (VME) Extensions for Instrumentation (VXI) technology into ATE, which is supposed to bring about the promise of interchangeable instrument components, ATE customers are forced to contend with system integration and software issues. One way the ATE customer can combat these problems is to have a separate Independent Verification and Validation (IV&V) organization employ rigorous methodologies to evaluate the correctness and quality of the ATE product throughout its life cycle. IV&V is a systems engineering process where verification determines if the ATE meets its specifications, and validation determines if the ATE performs to the customer's expectations.

IV&V has the highest potential payoff of assuring a safe and reliable system if it is initiated at the beginning of the acquisition life cycle and continued throughout the acceptance of the system. Fig. 1 demonstrates how studies have shown that IV&V effects are more pronounced when IV&V activities begin early in the software development life cycle, but later application of IV&V is still deemed to have a significant impact.

IV&V is an effective technique to reducing costs, schedule, and performance risks on the development of complex ATE, and a "tool" to efficiently and effectively manage ATE development risks. The IV&V organization has the ability to perform a focused and systematic technical evaluation of hardware and

software processes and products. When performed in parallel with the ATE development life cycle, IV&V provides for the early detection and identification of risk elements. The program is then able to take action to mitigate these risks early in the life cycle.

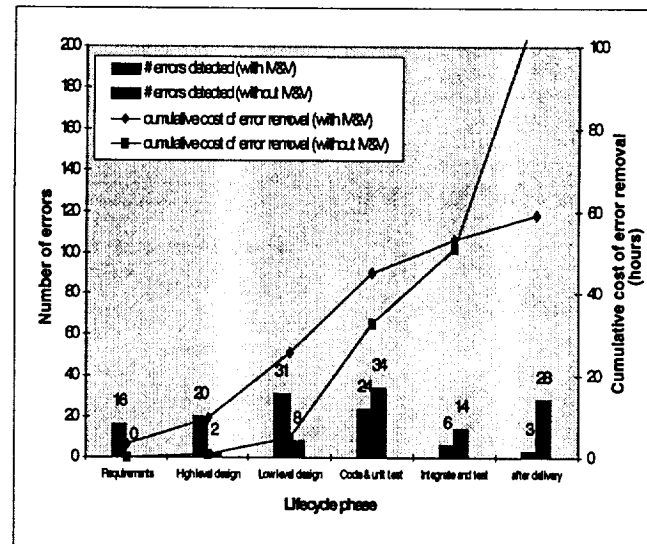


Fig. 1 IV&V Error Detection and Associated Cost (taken from briefing by James Arthur (Virginia Tech/LaRC), 10 Oct 96).

## II. IV&V TEAM MEMBERS

The IV&V team should consist of members from the ATE developer and program management sites, and the IV&V organization. The paradigm of IV&V is to locate analysts at the IV&V site, and the "eyes, ears, and position advocates" of IV&V at the ATE development and program management sites where physical presence is necessary for the exchange of information. The customer provides program management focus, while the developer provides for inside development requirement focus. With the developer, problems are

worked at the lowest level with the aim to resolve problems at earliest possible moment, thus requiring a small impact to correct.

### III. IV&V ACTIVITIES PRIOR TO LIFE CYCLE

Starting IV&V activities prior to the acquisition phase can lend itself optimum benefits. One large benefit would be the selection of a reliable, highly qualified organization to develop the ATE. The selection of the ATE development organization can be defined by the criticality of the ATE to be developed and the end cost. The following guidelines can be applied during the selection process:

- Develop a specification for function and performance of the desired ATE, along with defined measurable characteristics whenever possible.
- Select three or four candidate ATE that best meet the specification.
- Develop a comparison matrix that represents a head-to-head comparison of key functions.
- Evaluate each ATE based on past product quality, vendor support, product direction, reputation, etc.
- Contact current users of the ATE and ask for opinions.

In the final analysis, the selection of the ATE development organization should be based on the outcome of this process.

### IV. IV&V LIFE CYCLE ACTIVITIES

The following sections describe the IV&V activities that may be conducted during the acquisition, development, and maintenance of ATE. These IV&V activities may include the analysis, evaluation, review, inspection, assessment, and testing of whether the hardware and software of the ATE meet its system requirements.

#### A. Acquisition

During the acquisition phase the IV&V organization will assist program management in scoping the effort of IV&V required on the development project. The scope is determined so as to minimize the risk within the customer's budget. This is done by determining the objective of the IV&V (e.g. - technical complexity, safety, mission critical, security), the criticality and importance of the ATE, and the IV&V budget, including test facilities and tools as required. Once these steps are completed, the IV&V effort is tailored to fit the ATE development

program's need and a schedule for each IV&V task is defined along with the IV&V project plan.

Other important activities will include verifying that the contract specifies the correct program deliverables and schedule including definition of ownership, warranty, and copyright, and that the acceptance criteria and procedures for each deliverable are clearly, correctly, and completely specified. These activities can help ensure that when the ATE is delivered, items such as Prime Item Development Specifications are usable, and instrumentation operation capabilities met these specifications. A big problem in the past with ATE has been instruments that did not meet the performance requirements. For example, a test requirement calls for a 30-volt, 10-amp signal, and the power supplies in the ATE only supply up to a 20-volt, 5-amp signal. Or a 10-volt sine wave is required, and the function generator in the ATE only supplies a 9.23-volt sine wave.

#### B. Development

As illustrated in Fig. 2, ATE usually consists a conglomerate of four basic elements: controller, instruments, switching, and interface.

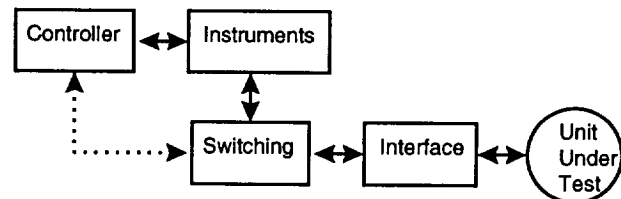


Fig. 2 ATE four basic elements.

The five key ATE software elements include the test program (source and object code), compiler, operating system, and the test executive as shown in Fig. 3.

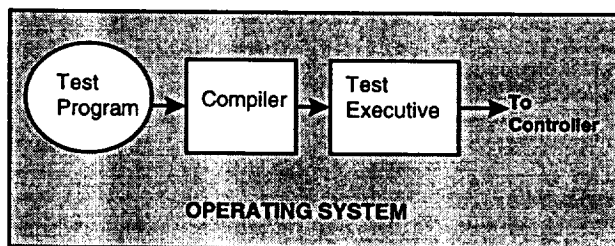


Fig. 3 Five key ATE software elements.

During ATE development, a continuous review of associated documentation is performed as part of the IV&V effort, and the software/system engineering

processes are closely monitored for any weak areas. Technical reviews and audits are assessed for the acceptability of the products under review and the extent to which milestones and life cycle goals are met. Assessing the reviews and audits increases program visibility and provides prioritized recommendations for corrective actions to maintain a focus on those problems posing the highest risk. Risk identification occurs throughout ATE development, identifying current and probable problem areas in the ATE development, and quantifying these risks associated with the problem areas, recommending alternatives to reduce the risks. Problem areas may consist of project risks (potential budgetary, schedule, personnel, resource, customer, and requirements problems and their impact on the development project) and technical risks (potential design, implementation, interfacing, verification, and maintenance problems).

### 1.) Requirements

During the requirements phase, the following IV&V activities ensure the correctness, completeness, accuracy, testability, and consistency of the performance and quality requirements:

**System requirements traceability analysis** - trace software and hardware requirements back to the system requirements in the Performance Specification and/or the Operational Concept Document.

**System requirements evaluation** - evaluate the Hardware Development Specification, Software Requirements Specification (SRS), and Interface Requirements Specification for readability, correctness, consistency, completeness, accuracy, and testability.

**Interface analysis** - Evaluate the Hardware Development Specification with controller, instruments, and interface panel requirements documentation, and the SRS with the hardware, user, operator, and software interface requirements documentation, for correctness, consistency, completeness, accuracy, and testability.

**Criticality analysis** - Determine the criticality and importance of each hardware and software requirement (catastrophic, critical, marginal, negligible)

**Hazard analysis** - Analyze system, hardware, software, and interface requirements to identify conditions, and factors which cause or contribute to a hazard, especially on ATE for nuclear testing.

**Configuration management assessment** - Assess the completeness and adequacy of the configuration management process.

### 2.) Design

The following IV&V activities during the design phase determine if the design of the ATE is a correct, accurate, and complete transformation of the system, hardware, and software requirements:

**Design traceability analysis** - Trace design document to requirements and development specifications, and vice versa for hardware and software. Analyze identified relationships for correctness, consistency, completeness, and accuracy.

**Design evaluation** - For hardware, evaluate equipment layout drawings; block diagrams, schematics, and logic diagrams with interface control drawings; Mock-ups, models, breadboards, or prototype hardware when appropriate; mechanical, electrical, and packaging design of consoles, racks, drawers, printed circuit boards, connectors, and instruments; firmware to be provided with the system; electromagnetic compatibility; and configuration item development schedule.

For software, evaluate functional flow; storage allocation data; control functions; computer software configuration item structure; development and test tools; security and safety; design, operation, and support documentation.

**Interface analysis** - Evaluate the hardware design document with controller, instruments, and interface panel requirements documentation, and the software design document with the hardware, user, operator, and software interface requirements documentation, for correctness, consistency, completeness, accuracy, and testability.

**Test analysis** - Verify design tests and criteria for component testing, integration testing, system testing, and acceptance testing.

**Hazard analysis** - For hardware, verify current and voltage characteristics of the switches; current levels imposed by Unit Under Test failures; environmental control and thermal aspects; and power generation and grounding. For software verify that critical logic design and associated data elements correctly implements the critical requirements and introduces no new hazards.

### 3.) Implementation

The following IV&V activities during the implementation phase verify and validate the transformation of design into the actual build of the hardware and software:

**Source code traceability** - Trace source code to corresponding design specification and vice versa.

Analyze identified relationships for correctness and completeness.

**Source code and documentation evaluation** - Evaluate source code for correctness, consistency, completeness, readability, testability, and accuracy. Evaluate source code for conformity with instituted standards, practices, and conventions. Validate source code against system requirements. Verify source code documentation (e.g. flowcharts, pseudo code, object diagrams) for completeness and consistency with source code.

**Hardware and software component test execution** - Perform IV&V component testing as required by the component test procedures of the hardware and software. Analyze results to determine that software and hardware correctly implements the design.

**Interface analysis** - For hardware, evaluate hardware with interface design documentation verifying that the test program/controller converts test program to machine code; controller and instruments transmits & receives instrument instructions and data; instruments and switching provides signal and signal routing to switch; and switching/interface panel mechanical and electrical interface conversion.

For software, evaluate source code with hardware, operator, and software interface design documentation for correctness, consistency, completeness, and accuracy.

**Hazard analysis** - Update Hazards Analysis as a result of code and hardware interface verification tasks.

#### 4.) Test

For the duration of the test phase, the following IV&V activities ensure that the software, hardware, and system requirements are satisfied by the execution of qualification and system tests:

**Traceability analysis** - Verify valid relationship between the requirements, test plan, test cases, and test procedures.

**Integration test execution** - Perform integration testing in accordance with test procedures. Analyze results to determine if hardware and software implements requirements and design, and that software and hardware components function correctly together. Document any discrepancies between actual and expected results.

**System test execution** - Perform system testing in accordance with test procedures. Analyze results to determine if hardware and software satisfies system objectives, and identify any hardware and software test limitations.

**Acceptance test execution** - Perform acceptance testing in accordance with test procedures. Analyze results to determine if hardware and software satisfies system objectives.

#### C. Maintenance

The maintenance IV&V activities addresses any modifications, enhancements, or additions to the hardware or software after the ATE has been delivered to the customer. Enhancements may include replacing existing ATE computer operating system with a PC. Additions may include adding a VXI card and software drivers to the ATE. The maintenance IV&V activities reapplies the IV&V activities of the definition and development phases, but do so in the context of the existing hardware and software.

### V. COST OF IV&V

Various sources have stated that the cost of IV&V can range from 10 - 50% of the ATE development cost. The cost will depend on the level of IV&V effort required. The degree or level of IV&V applied is determined by reliability and mission critical concerns and is proportionate to ATE development risk and function criticality. Criticality and development risks of each ATE function drives the amount of IV&V to be performed (e.g., detailed code analysis is performed only for more critical/high risk functions). How much IV&V versus criticality is then negotiated with the program management relative to availability of funding for IV&V.

### VI. BENEFITS

Applying IV&V in all phases of the life cycle can bring about various benefits. IV&V can offer the following benefits to the development and maintenance of ATE:

- Identify non-essential requirements which when eliminated reduce development, test, and maintenance cost.
- Identify the lack of a critical functional definition required for the execution of the command and control software of the ATE.
- Determine the actual performance of the ATE versus the performance specification when the

instrumentation parameters are critical to the ATE operating capability.

- Identify any risk associated with the interfaces of the VXI components.
- Permit fewer latent defects, resulting in reduced effort and time spent during testing and maintenance.
- Detect ambiguous or unclear specifications that can lead to the introduction of critical faults downstream in the development process.
- Reduce the effort required to fix individual faults.
- Provide higher ATE reliability resulting in greater customer satisfaction.
- Identify reusable components (requirements document, architectures, code, testing components) that may be used in future developments.
- Reduce maintenance costs.
- Reduce overall life cycle cost of ATE.

## VII. CONCLUSION

IV&V provides for increased visibility into the ATE development process and ensures the customer's needs are adequately reflected in the work. While a structured set of standards, procedures, and requirements can greatly improve the chances of producing a good result, these alone can not possibly

produce truly great products. While the IV&V organization should also review the standards and procedures, they must look beyond them to see if a first-class system engineering job is being performed and if key risks and feasibility issues are being addressed.

To prevent system integration problems of advancing sophisticated ATE, IV&V can counteract these problems by establishing high confidence in state-of-the-art ATE reliability, allowing for an open architecture system that will easily allow for the insertion of new instrumentation and software.

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